Estimate of pollutant emissions from fires in the wildland urban interface

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Progress for a Stronger Future

Wildland urban interface (WUI)

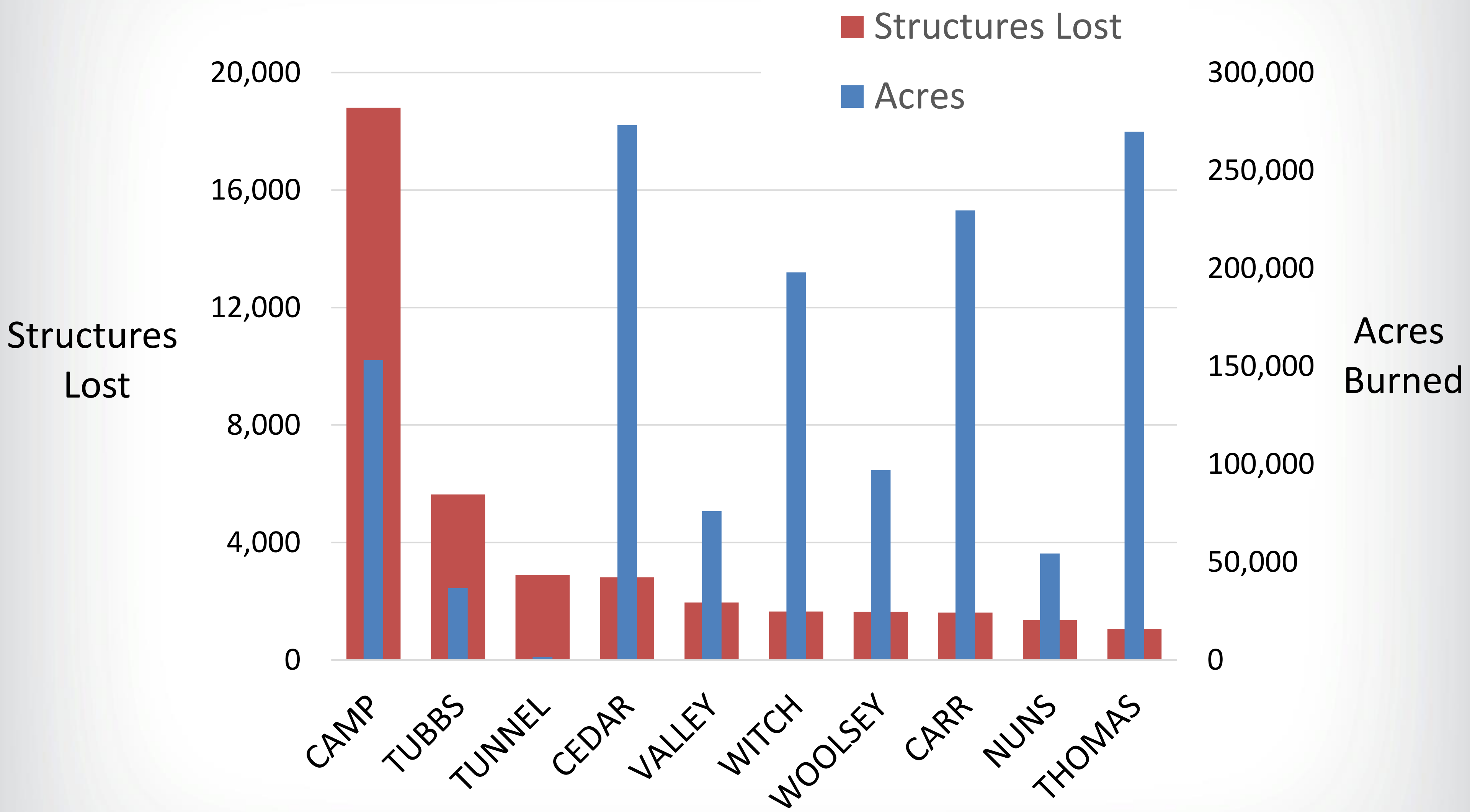
"Humans and their development meet or intermix with wildland fuel"

Source: https://www.usfa.fema.gov/wui_toolkit/

Defined in Federal Register 66 FR 751 p751-777, 2001:

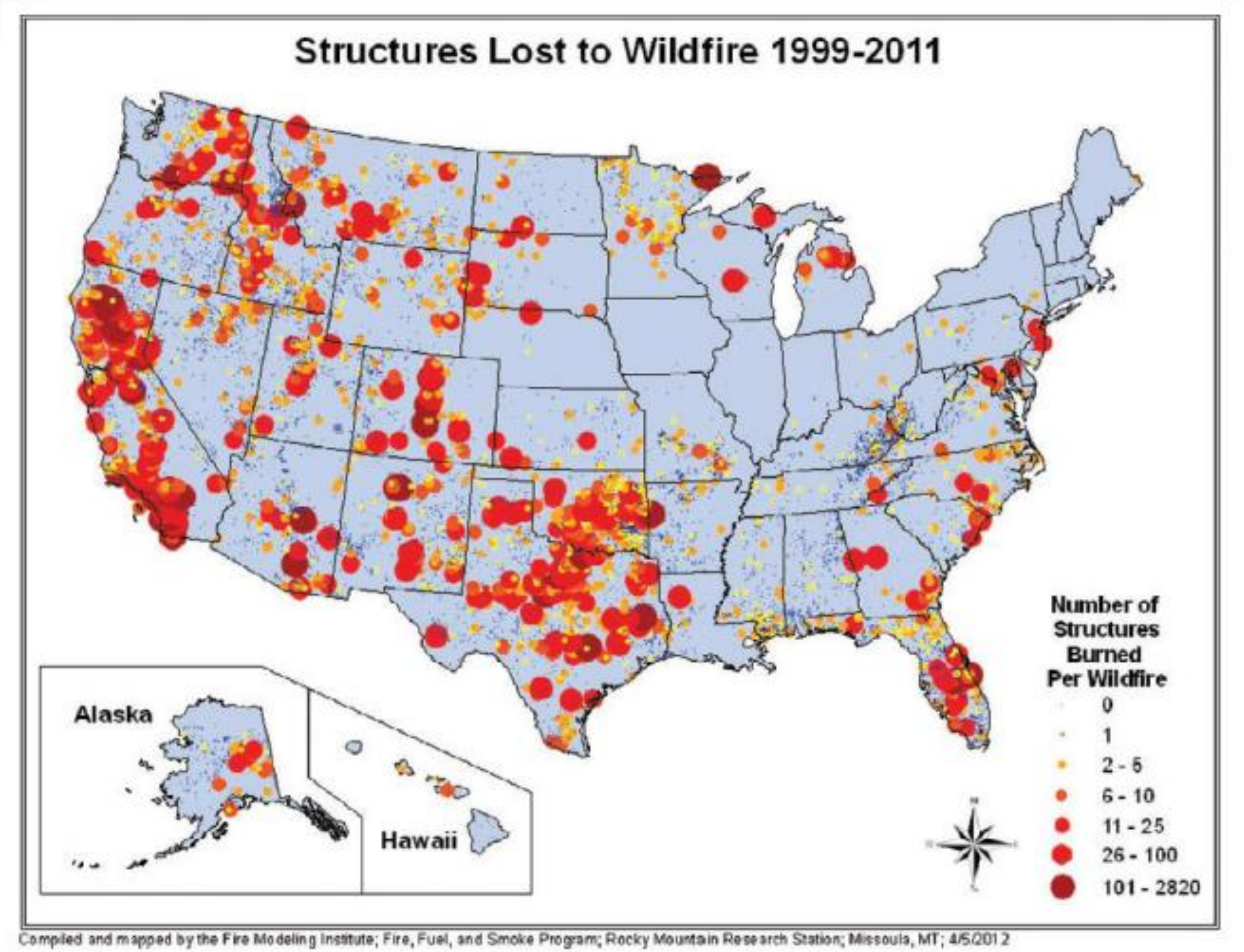
1) Intermix WUI is an area with at least 1 house per 40 acres where vegetation dominates
2) Interface WUI is an area with a larger population density adjacent to natural areas

Top 10 most destructive wildfires in CA



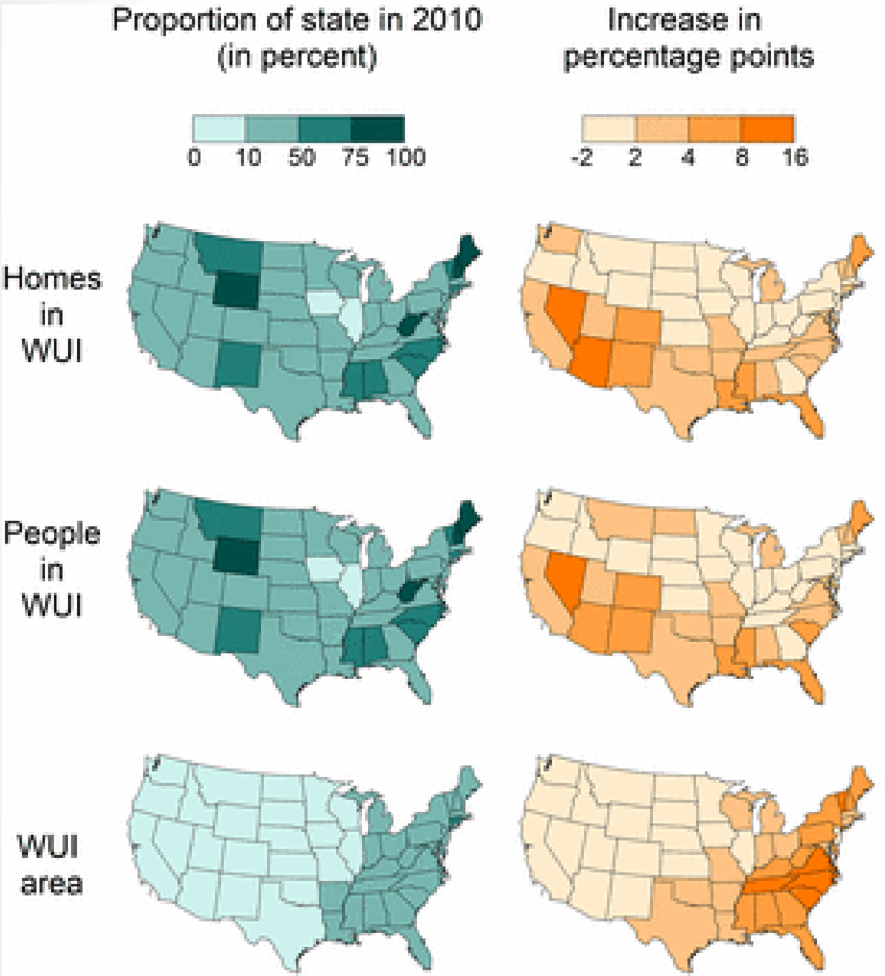
Source: CalFire https://www.fire.ca.gov/media/5511/top20_destruction.pdf

Structure loss in wildfires occurs all over the country



Source: Wildfire, Wildlands, and People: Understanding and preparing for wildfire in the wildland-urban interface, General Technical Report RMRS-GTR-200 USFS

WUI area, people, and homes are increasing



Source: Radeloff et al. 2017 Rapid growth of the US wildland-urban interface raises wildfire risk, PNAS 115:3314-3319.

Questions about the environmental impact of fires in WUI:

-What are the health impacts of smoke on exposed populations?

-What are the environmental effects of WUI fires and extinguishing agents?

-What are the chemical constituents of smoke from fires in the WUI and how do they differ from natural fuels?

Study Objective

What are the chemical constituents of smoke from fires in the WUI and how much are emitted?

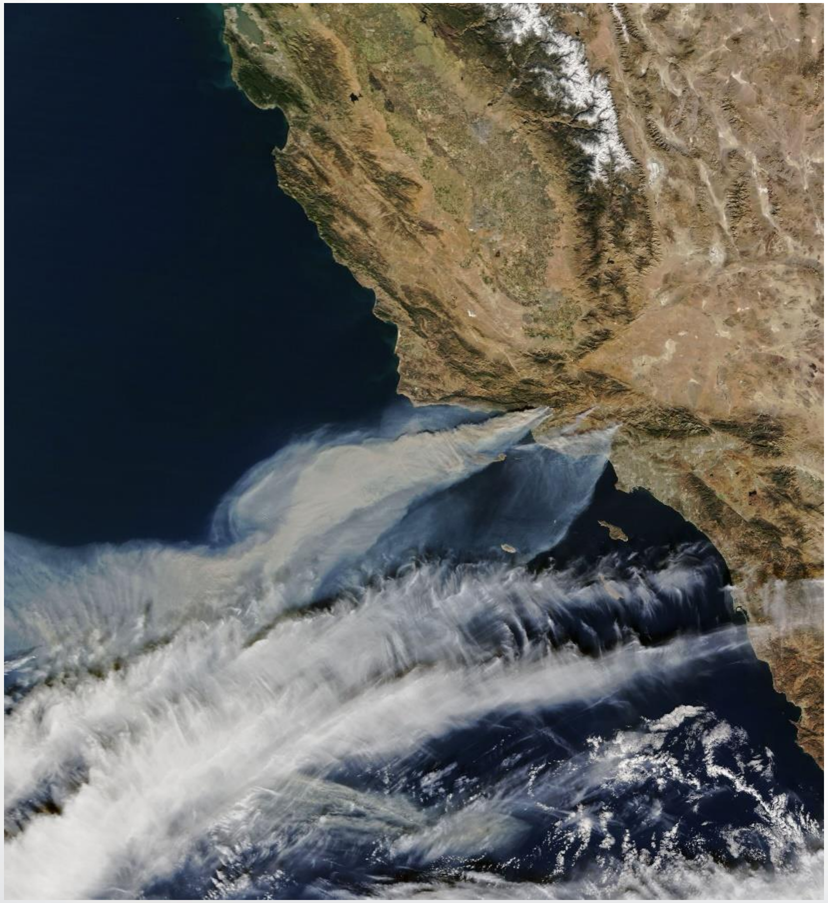
Assess the relative importance of structures and vehicles to wildfire emissions by developing an emissions inventory for a single fire in the WUI

Approach

1) Select a wildfire with documented structure losses occuring during an National Emissions Inventory (NEI) year (e.g. 2017, 2014, 2011)
2) Assess current inventory methods for structures and vehicles
3) Summarize state of knowledge of emission factors for buildings, vehicles, and their components
4) Refine inventory to arrive at best guess of criteria and hazardous air pollutant emissions from structures/vehicles

Thomas Fire – December 2017 Ventura County, CA

- Started as a small lightning ignited brush fire in the hills surrounding Santa Barbara December 4th that rapidly expanded
- Hot, dry, and windy conditions lead to a firestorm resulting in > 100,000 acres burned in 3 days



- The fire swept through multiple neighborhoods in Ventura and surrounding towns ultimately destroying 1065 homes

How do we inventory structure fire emissions?

$$E_x = A \times B \times FB \times EF_x$$

E_x = mass of emissions of species x
A = activity (e.g. number of houses or vehicles)
B = mass of fuel available to burn
FB = fraction of the fuel that burns
EF_x = emission factor, i.e. mass emitted per unit fuel

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The fuel amount, fraction burned, and emission factors are all highly uncertain

Overview of Structure Fire Inventory Methods

There are two methods that specify B, FB, and EF_x:

(1) CARB 1999 – Section 7.14 Structure and Automobile Fires (https://ww3.arb.ca.gov/ei/areasrc/arbmiscprocfires.htm)

(2) SP 2009 – Blomqvist and McNamee 2009, Estimation of CO2 Emissions from fires in dwellings, schools and cars in the Nordic Countries, SP Technical Note 2009:13

We refined and combined these methods to develop our own (EPA-WUI 2020)

CARB 1999 – Structure Fires: Assumptions

- Average house is 1,649 sq ft (1999 census data), with 11 tons of lumber (National Association of Home Builders)
- Average structure loss is 7.3% based on insurance estimates
- Average combustible content is 7.9 lbs/sq ft (National Bureau of Standards) calculated by the weighted average of content in rooms where fires happen most frequently
- Emission Factors are from burning a model wood building (Butler and Darley, 1972)

	Total Organic Gases	Carbon Monoxide	NOx [a]	SOx	PM
lbs/Ton	13.9	168.0	4	0	10.8

[a] Derived from burning municipal refuse

Images from the houses in Ventura County, CA

Images from the houses in Ventura County, CA

SP 2009: Structures

Commissioned by the Swedish Insurance Federation update of previous inventory method but calculates only CO_2 emissions

- Structure loss was determined from interviews with fire investigators:
  - 5% when fire is restricted to room of origin
  - 35% when fire spread to a few rooms
  - 80% when fire spread to multiple buildings
- Combustibles obtained from an inventory of a Skanska-IKEA development = 3.69 lb combustible content / sq ft
- Applies a mass distribution of materials (e.g. PVC, wood, cotton) and EFs for specific materials

EPA WUI 2020 – Structure Fires: Assumptions

- Average house is 2,140 sq ft (2010 census data), with 14 tons of combustible material (i.e. lumber, National Association of Home Builders)
- Average structure loss is 80% following SP 2009
- Average combustible content is 5.64 lbs/sq ft (Survey of Canadian homes Bwalya et al. 2004)

Material	Structure	Combustibles
Wood	95%	80%
Other	5%	20%

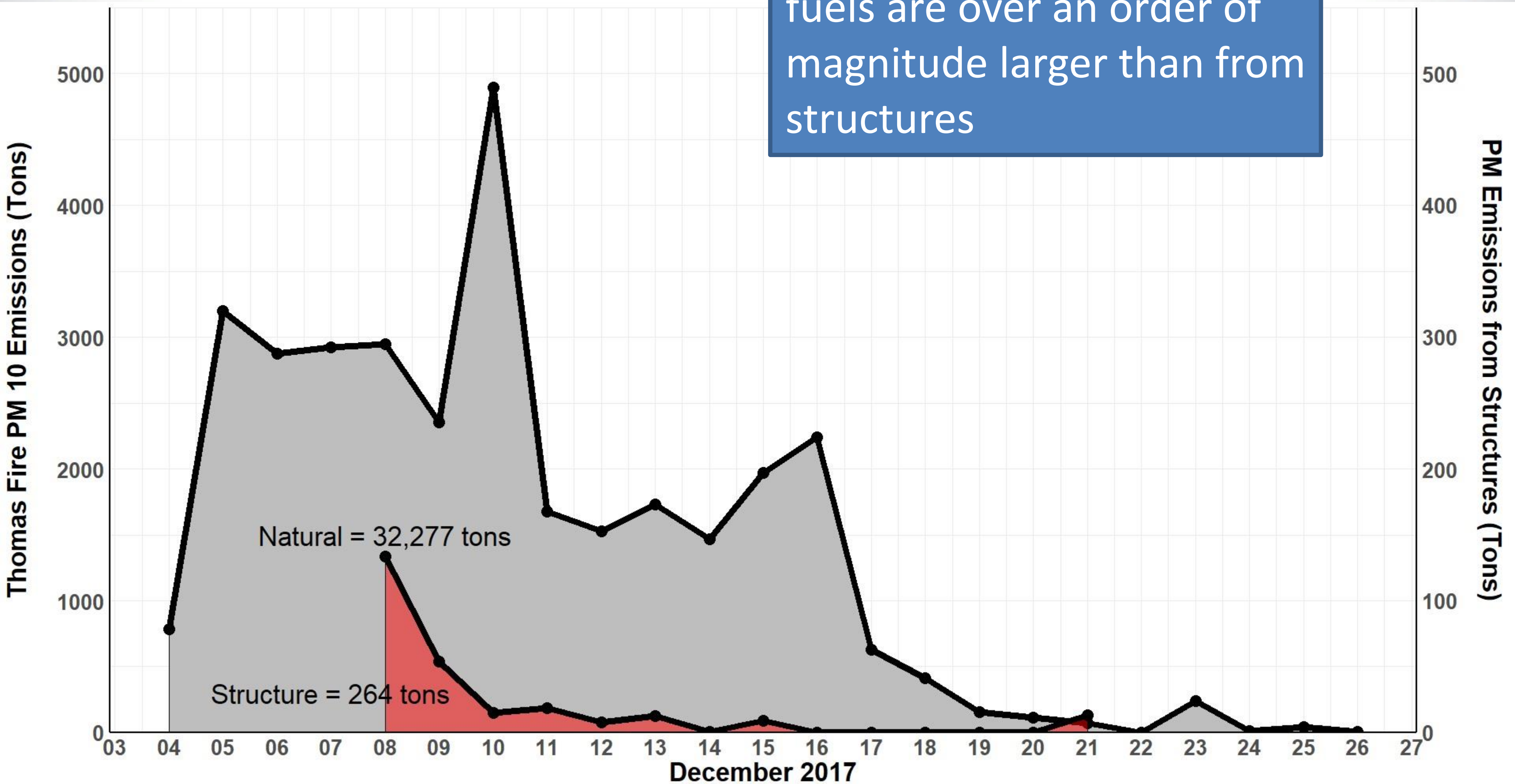
- Average EFs from 5 studies of wood and wood products and 12 studies of furnishings and materials to approximate EFs from 'other' materials in the home

lb/ton	Total Organic Gases [a]	CO	NOx	SO2	PM
Wood	13.9	118	2.8	-	17.2
Other	13.9	266	12.4	168	162.9

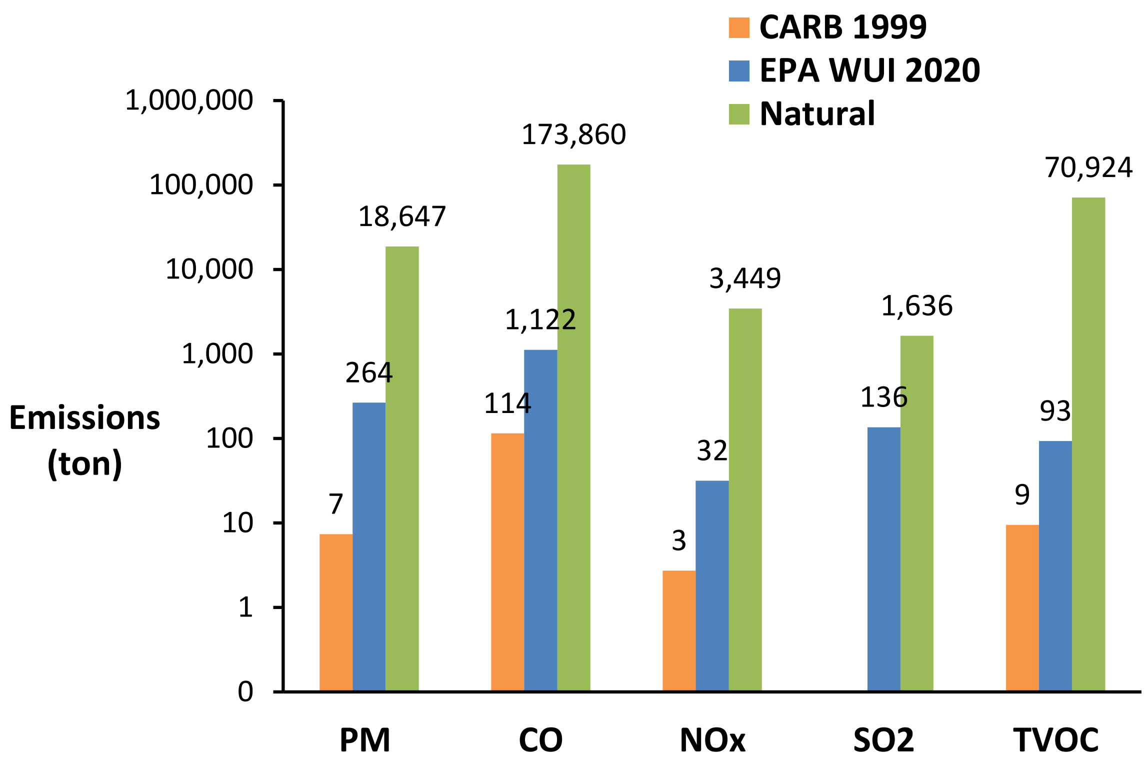
	Number of EF Records	WUI Average (lb/ton)	Coefficient of Variation (%)	Natural Average (lb/ton)	Coefficient of Variation (%)	WUI / Natural (%)
PM	97	133.5	127%	44.9	75%	**197%**
CO	145	247.0	105%	198.1	50%	**25%**
HCN	49	17.5	474%	0.82	98%	**2,038%**
NOx	21	11.5	338%	6.04	70%	**90%**
HCl	32	22.8	263%	2.77	137%	**126,567%**
SO_2	14	306.5	263%	0.24	65%	**5,518%**
Benzene	41	125.1	214%	2.23	72%	**8,659%**
Toluene	38	62.8	192%	0.72	86%	**402%**
Xylenes	18	2.30	270%	0.458	34%	**1,396%**
Styrene	16	0.69	213%	0.060	92%	**4,482%**
Formaldehyde	23	2.48	135%	0.166	58%	**-56%**
Acetaldehyde	23	6.80	155%	0.148	79%	**-9%**
Acrolein	12	4.02	224%	0.119	69%	**-88%**
Naphthalene	10	0.20	110%	0.180	80%	**3,272%**
Benzo(a)pyrene	18	0.14	156%	0.122	59%	**36,499%**
Benzo(a)anthracene	22	1.36	166%	3.110	39%	**45,213%**
Benzo(g,h,i)perylene	16	1.69	107%	1.865	46%	**76,397%**
Diebenzo(a,h)anthracene	17	0.17	150%	1.403	46%	**255,170%**
Acenaphthylene	16	0.24	95%	0.001	93%	**10,443%**
Dioxins (PCCD)	4	0.18	196%	0.000	62%	**1,536%**
Furans (PCDF)	4	0.14	199%	0.000	81%	**66,603%**

Results: Time series PM10 emissions from the Thomas Fire

PM emissions from natural fuels are over an order of magnitude larger than from structures

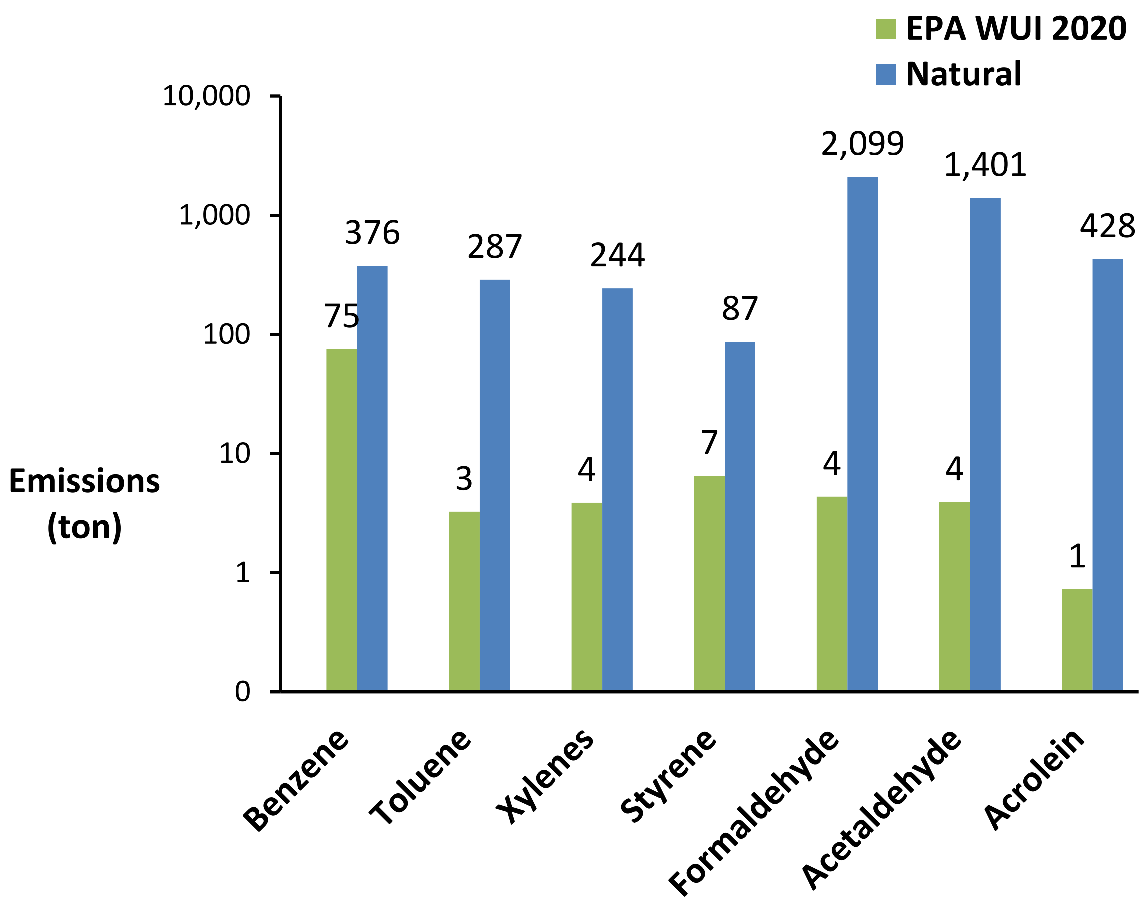


Results: Total criteria emissions from the Thomas Fire



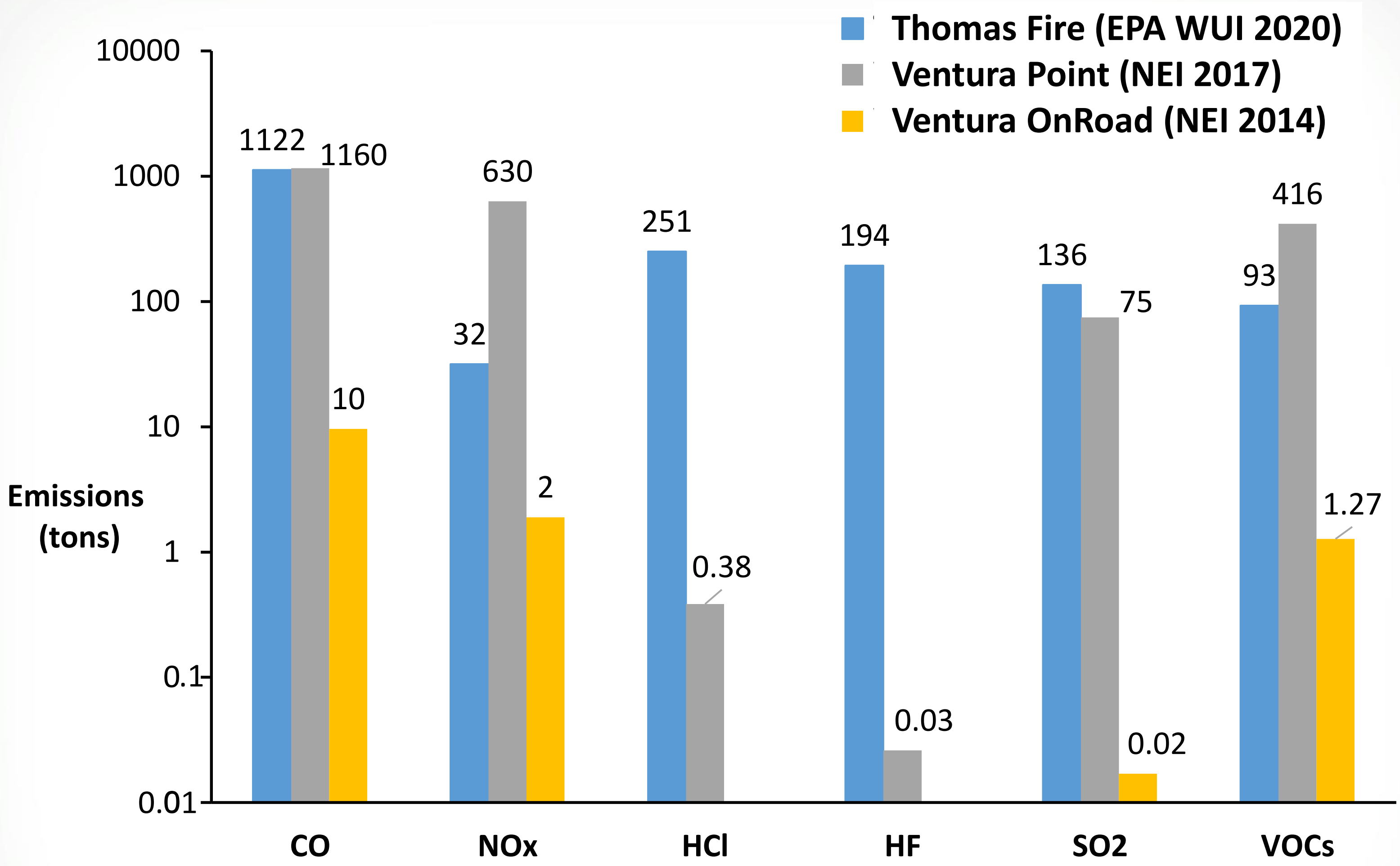
The assumptions used to estimate emissions have order of magnitude impact on estimates

Results: Total hazardous air pollutant emissions from the Thomas Fire

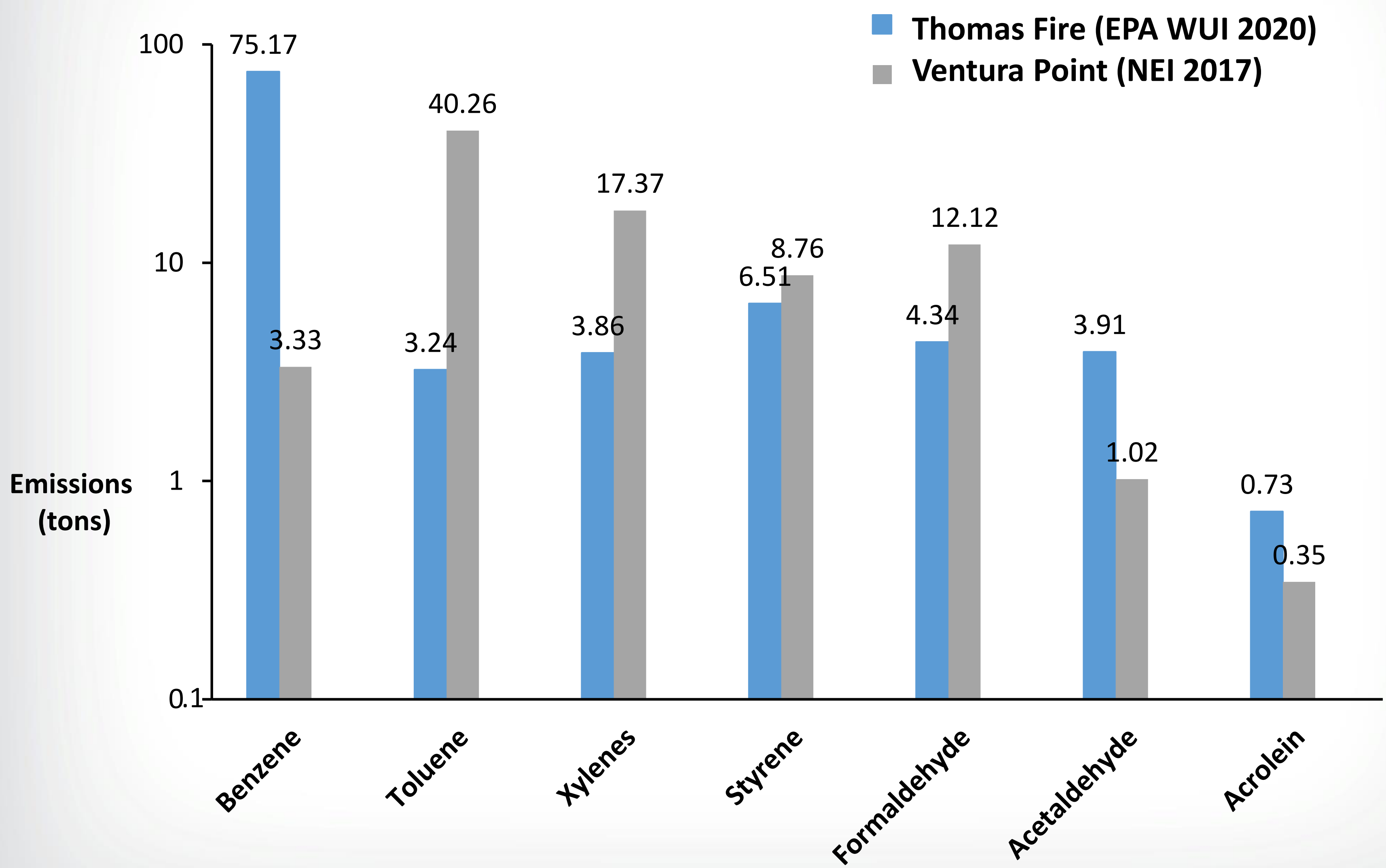


For some species the gap between structures and natural fuels is narrowed

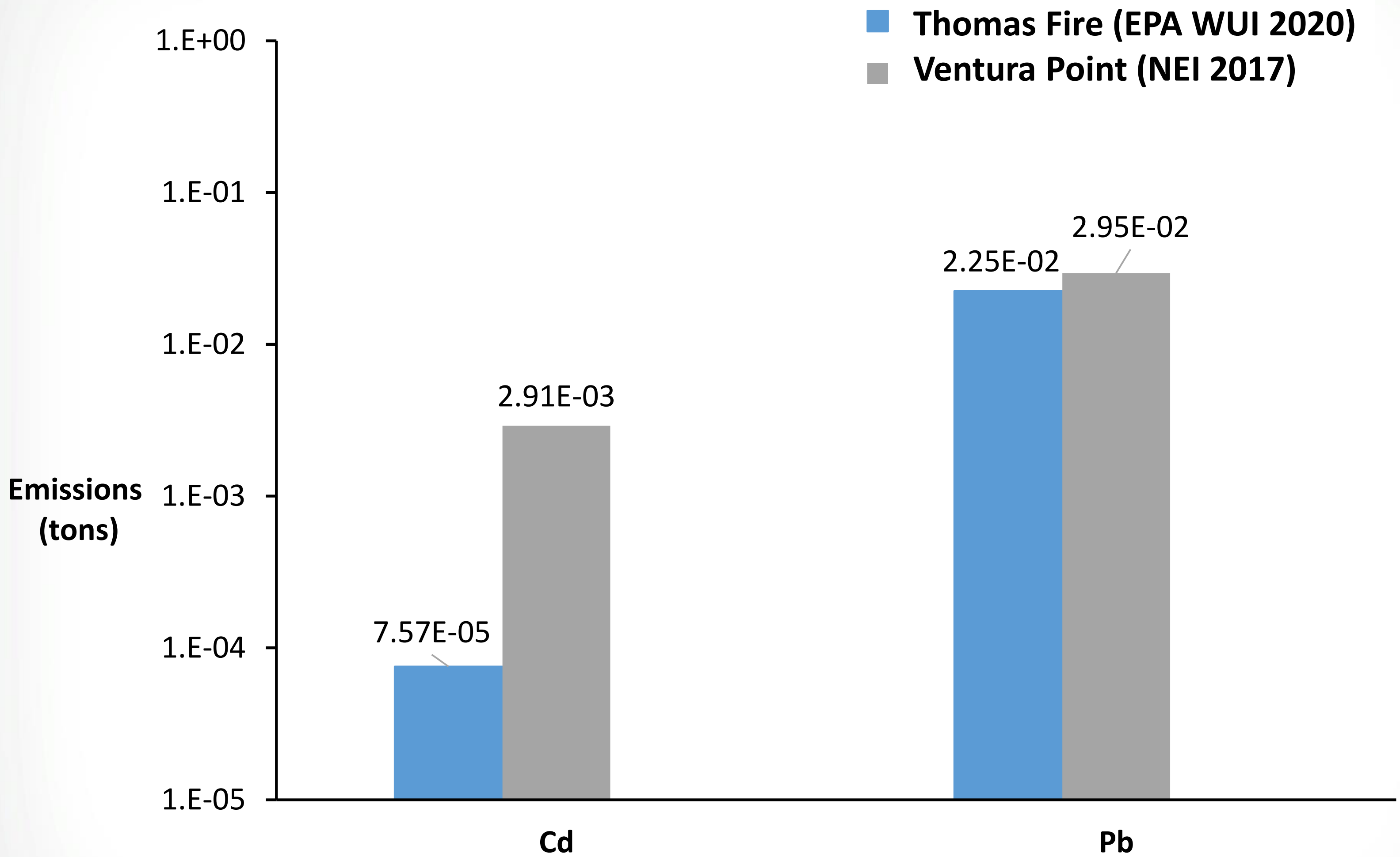
Results: WUI structure emissions compared to other Ventura Co. sources



Results: Structure HAP emissions compared to other Ventura Co sources



Results: Structure toxic metal emissions compared to other Ventura Co sources



A few take away points

- Emissions of criteria pollutants from structures in the WUI are miniscule compared to those from the natural fuels for the Thomas Fire
- However, some air toxics (e.g. benzene, styrene, Pb) are emitted in amounts many times larger than the from the natural fuels and are comparable to other point sources on a county wide basis
- Importance of WUI emissions will depend on the individual wildfire/WUI fire, but exposure may be higher to WUI fire emissions due to the close proximity of the public

Some comments on the methods

- Methods used for municipal fires are not applicable to WUI fires
- We need more emission factors to fill in the data gaps in the literature, especially for PM and its composition